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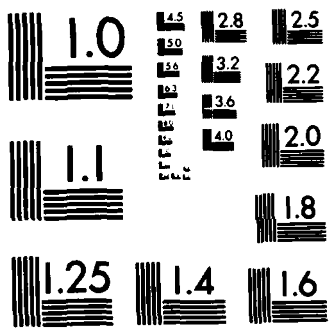

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DEPARTMENT OF THE AIR FORCE

AIR UNIVERSITY (ATC)

AIR FORCE INSTITUTE OF TECHNOLOGY

Wright-Patterson Air Force Base, Ohio

A LIFE CYCLE COST ANALYSIS FOR THE PROCUREMENT OF GENERAL PURPOSE VEHICLES

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LSSR 19-82

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The Air Force procures commercial general purpose vehicles based on lowest acquisition costs, under the assumption that Operations and Maintenance (O&M) costs are the same for similar vehicle types. The assumption is made because of lack of conclusive proof that O&M costs are significantly different. This paper addresses whether the Air Force should continue the present procurement strategy, or procure vehicles based on total Life Cycle Cost (LCC) acquisition techniques. Statistical analysis indicates that LCCs of two makes of one type of commercial vehicle (pickup trucks) are not equal, based on a sample of 70 vehicles selected from six bases. The results suggest that LCC procurement strategies should be further investigated, especially for multi-year and other large scale buy programs.

LSSR 19-82

A LIFE CYCLE COST ANALYSIS FOR THE PROCUREMENT OF GENERAL PURPOSE VEHICLES

A Thesis

Presented to the Faculty of the School of Systems and Logistics

of the Air Force Institute of Technology

Air University

In Partial Fulfillment of the Requirements for the

Degree of Master of Science in Logistics Management

By

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and

Captain Jeffery B. Webb

has been accepted by the undersigned on behalf of the faculty of the School of Systems and Logistics in partial fulfillment of the requirements for the degree of

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CHAPTER I

INTRODUCTION

Background

The procurement and management of vehicles in the Air Force is big business. As an illustration, vehicle fleet managers are responsible for the operation and support of an inventory which consisted of 98,274 vehicles, valued at $2.5 billion, as of January 1982 (6). Fleet managers and staff personnel are also responsible for annual large-scale procurement programs in order to maintain a reliable fleet within budgetary constraints. For example, 8,813 vehicles were funded in Fiscal Year 1981 (FY81) (6). Of these, 4,529 were general purpose passenger and cargo vehicles such as sedans, station wagons, busses and pickup trucks, that satisfy general automotive transportation needs (23:A-3). The remaining 4,284 vehicles funded in FY81 were special purpose vehicles, which are classified as vehicles designed for a special requirement, such as aircraft towing tractors and material handling equipment (23:A-3). Since the Air Force has determined that purchasing commercial vehicles on a competitive basis minimizes acquisition costs, 94 percent of the Air Force fleet consists of commercially designed general and special

purpose vehicles (6). The focus of this study concerns the procurement practices for the general purpose vehicles of commercial design.

The goal of the Air Force vehicle fleet management program and, in particular, the procurement strategies, is to provide reliable vehicles to support the Air Force mission at the lowest total life cycle cost. Life cycle cost components include acquisition, operation and maintenance, and disposal costs. Operation and maintenance (O&M) costs, which include such elements as fuel, parts and maintenance labor, are considered over the life of the vehicle and may amount to as much as 75 percent of the total life cycle costs (9:349). In FY81 alone, 16.7 million man-hours were expended in maintaining the vehicle fleet. This represents a substantial cost consideration (6).

The Air Force procures commercially designed general purpose vehicles based upon competitive acquisition cost bidding (11:2). This practice is used in lieu of procurement based upon life cycle cost competition common to the acquisition of major weapon systems, for two major reasons. First, life cycle cost acquisition requires reliability and maintainability (RAM) testing in order to build up sufficient operation and maintenance data to project O&M costs over the life of the vehicles. Purchasing a sample of competitor vehicles and having a

controlled "drive-off" competition to collect the historical data is considered to be time-consuming and cost prohibitive (8:1). Second, the Air Force

> . . . operates under the working assumption that if a product is commercially produced and has met the test of the marketplace, then it is comparable in life cycle O&M costs to other like commercial vehicles [8:1].

The assumption is made because the Air Force has been unable to conclusively prove otherwise (8:1).

Although LCC acquisition is not used, attempts to reduce cost have been centered on reducing the proliferation of makes and models. The Air Force purchases a variety of numbers and types of vehicles. For example, in 1978 the Air Force procured 523 Chevrolet and 323 Dodge pickup trucks. The following year, the Air Force bought 20 Chevrolet and 202 Dodge pickups, and in 1980, 295 Dodge and 12 Ford pickups were procured (15). These statistics represent only a portion of the vehicles bought each year since there are approximately 330 vehicle types in the inventory (22:40). This proliferation of makes and models results in nonstandard fleets and increases the cost of maintenance and support. The increases in costs can be attributed, in part, to the requirement to maintain multiple parts inventories, multiple sets of technical manuals, and additional training of vehicle mechanics (8:2). For example, if a vehicle maintenance shop supports Dodge, Chevrolet, and Ford pickup trucks, three separate

inventories of engine components such as spark plugs and electronic ignition sets, and three separate technical manual sets must be maintained. Further, mechanics must have proper training to maintain the three different truck systems. These factors not only increase maintenance and support costs, but increase the administrative burden as well. Current attempts to standardize the vehicle fleet bring into light a greater possibility for the application of LCC procurement techniques.

Problem Statement

The Air Force procures commercial general purpose vehicles based on lowest acquisition cost, under the assumption that O&M costs are the same for all makes of similar vehicle types. The assumption is made because the Air Force is unable to conclusively prove otherwise. Since O&M costs may be as high as 75 percent of the life cycle cost of a system over its useful life, the DOD preferred procurement strategy is based on total life cycle costs. However, if general purpose vehicles have similar O&M costs, the costs and time of drive-off competition would not justify life cycle costs acquisition strategies. The problem this research addresses is whether the Air Force should continue the present strategy of purchasing commercial general purpose vehicles based on acquisition cost or

procure vehicles based on total life cycle cost acquisition techniques.

Research Objectives

The general objective of this research is to gather data to compare the costs of operating and maintaining selected makes of pickup trucks procured by the Air Force. The supporting objectives include:

1. Determine if there is a significant difference in the life cycle costs of Chevrolet and Dodge pickup trucks.

2. Recommend or confirm procurement strategies based upon the research findings.

Research Question and Hypothesis

The following question guided the development of this research: Is there a difference in the life cycle cost of Chevrolet and Dodge pickup trucks?

The answer to the research question will be used in addressing the following hypothesis: There is a difference between Chevrolet and Dodge operations and maintenance costs and life cycle cost procurement techniques should be applied in the acquisition of general purpose vehicles.

Scope

In order to assemble sufficient data to scientifically determine any significant differences in the life cycle costs of different vehicle makes, we will research 1978 Dodge and Chevrolet one-half-ton pickup trucks. Pickup trucks are one of the most numerous of all U.S. Air Force general purpose vehicles; therefore, it was believed that limiting the scope of the research to specific makes of one-half-ton pickup trucks would result in sufficient data for analysis. The year 1978 was selected since the vehicle would be entering the mid-way point of its expected life of seven years. It was assumed that a truer representation of maintenance cost data could be obtained from vehicles of this age, as contrasted with vehicles that were at the beginning or end of their life cycle. In the 1978 time frame, the Air Force did not purchase sufficient quantities of all three manufacturer types to allow statistical study. Therefore, it was decided to study only the Dodge and Chevrolet one-half-ton trucks.

Limitations

There are two limitations on the research effort:

1. Due to the restricted time and funds available for collecting data, a sample of convenience was used to provide vehicle life cycle cost information. The following

Air Force bases were used as the sample of convenience data collection points: Beale, Travis, Carswell, Randolph, Lackland, Tyndall, and Kelly.

2. The conclusions derived from this research can be applied to the procurement practices for one-half-ton pickup trucks. Limited generalization of the research conclusions can be applied to other vehicular types, but for specific conclusions to be made, each vehicle type would have to be studied. However, the methodology contained in this paper could be applied in the research of procurement practices for the other types of vehicles.

An Existing Need for Research

One may question the need to research operations and maintenance cost differences between similar types of Air Force vehicles. In fact, there is a twofold need. First, the Air Force assumes that O&M costs are the same for similar types of Air Force vehicles, and bases the procurement strategies on this assumption. Since LCC studies show that O&M costs may amount to as much as 75 percent of a system's total life cycle costs (9:349), empirical research is needed to support the assumption concerning such a large cost category. If empirical research indicates that there are no differences in O&M costs between similar types of commercially procured vehicles, then the current procurement strategy based on acquisition cost

competition is appropriate. Second, if it is shown that there are significant differences in O&M costs between similar types of vehicles, it is important to know the magnitude of the differences. If the cost magnitude is relatively small, then the cost of LCC procurement is not justified and acquisition cost competition along with strategies to standardize the fleet are appropriate. However, if the O&M cost differences are large, then LCC procurement techniques should be considered, especially with long-term commitments, such as multiyear buy programs, that require the Air Force to utilize sole source contractors.

Literature Review

The literature review covers procurement strategies for Air Force vehicles. Included in these strategies are multiyear procurement, block buys, and family group buys. The remainder of the literature review includes a discussion of life cycle cost acquisition.

Procurement Strategies for Air Force Vehicles

Since the Revolutionary War the United States Government has purchased materials and services from the commercial market to meet its defense needs. The Constitution allows Congressional funding ". . . to raise and support Armies, but no appropriation of money to that use

shall be for longer term than two years [19:4]." In the early years of this country there were few major weapons systems. Except for ships, all defense purchases could be filled in one year (4:21).

Due to the nature and complexity of modern defense weapon systems, this has changed dramatically. The time to identify, plan, and manufacture a major system has increased significantly. It now may take as long as seventeen years to identify a mission need and then procure a system to meet that need. Procuring modern weapons and arms is expensive and consumes a major portion of the defense budget. For example, in 1981, the federal budget included $57 billion for major system research and development (R&D) and procurement. This represented 8.2 percent of the federal budget (14:422-423). It is therefore imperative that the defense procurement strategies be as sophisticated as the systems they are designed to purchase.

The current vehicle procurement strategy is single year procurement. Single year procurement is an acquisition process that results from annual funding. Contracting law and public policy makes single year procurement the preferred method of acquisition. In a single year procurement contract, authorization and appropriation is limited to one year (8:4). This policy prohibits contracting for more end items than can be purchased with available annual funds (4:28).

Multiyear Procurement. In a recent effort to standardize the vehicle fleet, other procurement strategies are being investigated. One of these strategies is multiyear procurement. Multiyear procurement is a generic term used to describe a situation where the government contracts, to some degree, for more than the current year requirement. The Defense Acquisition Regulation (DAR) defines multiyear contracting as ". . . a method of acquiring for DOD planned requirements for up to a five year period . . . without having total funds available at time of award [24:1-322.1(2)]." Presently under the DAR, the first year of the contract is initially funded.

The DAR only allows a multiyear contract when certain criteria are met. A multiyear contract is not allowed for advanced buys of materials or items because of offered price breaks (4:31). Two provisions of the DAR must be met: "The government need for the supplies or services being acquired over the period of the contract is reasonably firm and continuing [24:1-322.1(c)(1)ii]," and ". . . such a contract will serve the best interest of the government . . . by promoting economies of performance and operations [24:1-322.1(c)(1)ii)]."

1. Advantages of Multiyear Procurement Strategies. Advantages to the government can be found in the DAR. The DAR, as a culmination of policy and legislation, encourages

multiyear procurement when one or more of the following advantages can be realized (24:1-322):

a. Lower cost;

b. Enhancement of standardization;

c. Reduction of administrative burden in the placement and administration of contracts;

d. Substantial continuity of production or performance, thus avoiding annual startup costs, make ready expenses, and phaseout costs;

e. Stabilization of work forces;

f. Avoidance of the need for establishing and "proving out" quality control technique and procedures for a new contract each year;

g. Broadening the competitive base with opportunity for participation by firms not otherwise willing or able to compete; and

h. Implementation of the Industrial Preparedness Program for planned items with planned producers.

It is significant to note that six out of the eight advantages involve cost. Cost is a major concern for the entire federal budget and because the Defense Department will consume 29 percent of the proposed 1983 federal budget, it is imperative that the DOD reduce cost of major system procurement. DOD officials estimate that savings from multiyear procurement could run as high as $5 billion dollars in 1981 (4:81-82).

2. <u>Disadvantages of Multiyear Procurement Strategies</u>. The before-mentioned concern of Congress, that MYP contracts will increase commitments in defense dollars and reduce flexibility, is not unfounded. Multiyear contracts do commit large amounts of dollars to successive years. If a succeeding Congress decides to cancel a multiyear contract then it is required to authorize appropriations to pay the cancellation penalty (4:87).

This lack of flexibility may force decisions to enhance weapons already in production when it would be more advantageous to develop new alternatives to an emerging threat. This could cause the DOD to forego revolutionary technology (4:89).

The most obvious disadvantage to MYP is the government's liability in case of cancellation. Payment of these charges could be quite substantial and in an era of tight budgetary constraints may lead to loss of additional hardware and public criticism. Although the problem could be serious, there is no evidence of excessive cancellation. From 1976-1980, only 33 of 1097 multiyear contracts were cancelled (4:89).

Another disadvantage is caused by the amount of up-front money that is required for a multiyear contract. The DOD is already working with a limited budget and large expenditures of funds on MYP contracts reduces the amount

of available dollars. A shortage of funds due to MYP may cause another program to be limited or cancelled (4:90-91).

<u>Block and Family</u>. The DOD is constantly searching for other new procurement techniques in addition to multi-year procurement. Two new strategies that the Air Force is trying include block buys and family group buys. These strategies have only been applied to vehicular solicitations in the past year.

Block buys consist of buying large quantities of an item one year and then not buying any of the items for the following two or three years. This approach is most appropriate when an item has pure commercial applications.

Family group buys consist of combining vehicles solicitations of a number of like items so that the "whole family" will be bought from one manufacturer. An example would involve combining the purchases of five-ton truck tractors, ten-ton truck tractors and five-ton dump trucks into one solicitation. This approach can be used in both block and multiyear purchases. Again, it is best suited for commercial design vehicles with a number of contractors which produce a full line of products.

These strategies reflect the fact that while the Air Force does not apply life cycle cost acquisition techniques, procurement programs are being pursued to minimize

the controllable costs (8:1). Life cycle cost acquisition techniques will be discussed in the next section.

Life Cycle Cost Acquisition

Life cycle costing (LCC) is a procurement method that takes into consideration the total cost of a product over its useful life (3:v). Many products are bought on the basis of the lowest purchase price possible. However, systems differ in the amount of maintenance time required, energy used, and number of personnel required to operate them over their life cycle. Thus, there can be many other cost differences in addition to purchase price, all of which should be considered when buying a system or product. The importance of LCC is amplified by the fact that operating and maintenance costs can be as much as 75 percent of the total cost of a system (9:349). With decreasing budgets, it is important to cut procurement cost and still receive what is needed. Life cycle costing procurement has this capability.

An appropriate discussion of LCC breakdown structure can be found in Blanchard (see Figure 1-1). Blanchard breaks total system cost into four categories--research and development, investment, operations and support, and disposal (2:p.12-5). In Air Force vehicle acquisition, research and development and investment costs are included in the prorated acquisition cost of the vehicle. For

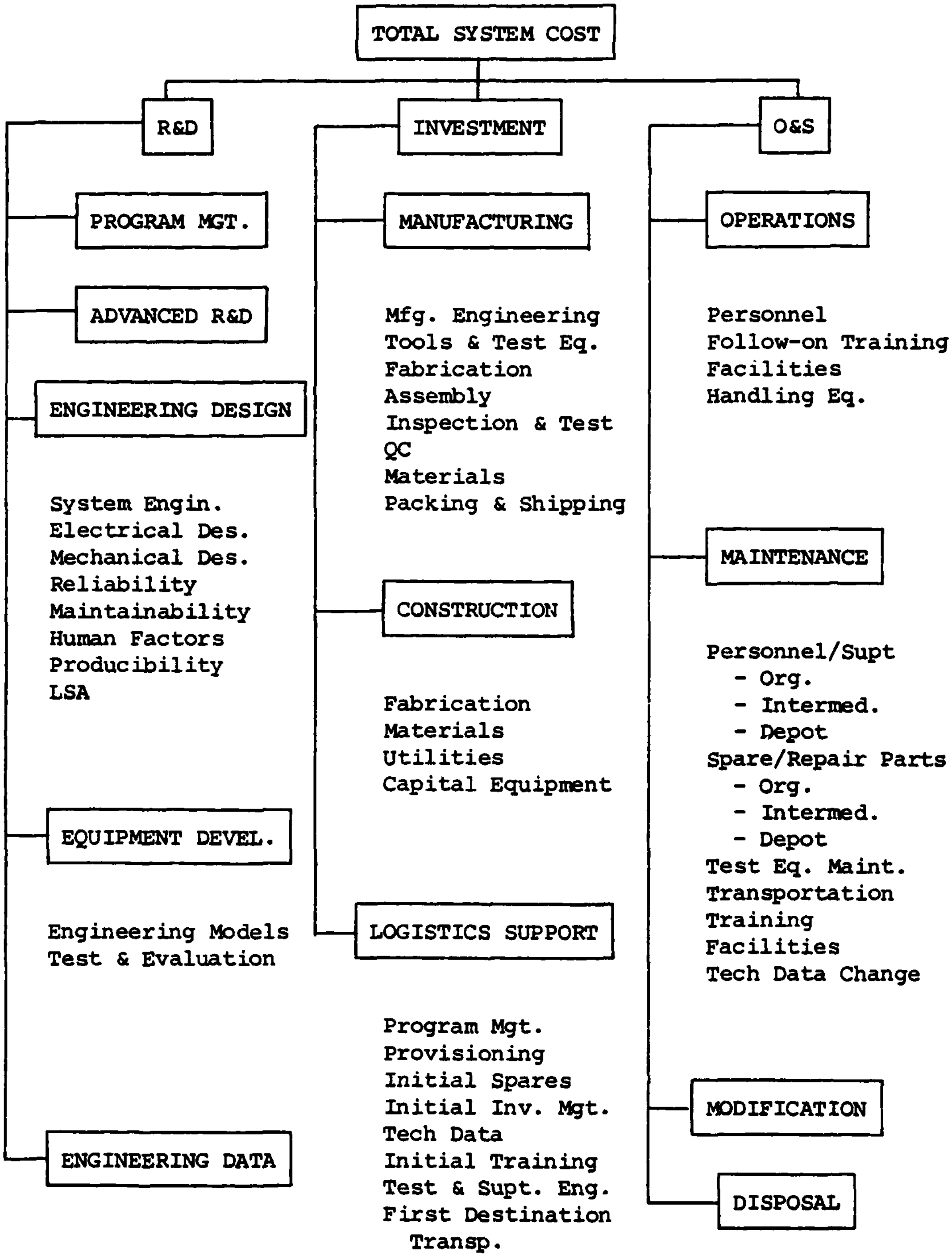

Fig. 1-1. LCC Breakdown Structure (2:p.12-5)

example, Ford does all its research and testing prior to start of production. These costs are then included with the acquisition cost of the vehicle.

When manufacturers develop a product, they have a specific market in mind and they design the product appropriately. For example, for years the Air Force bought F-100/F-102/F-106 aircraft tires which met specification requirements, and bought the tires at the lowest purchase price available. According to Kankey (10:29), this practice revealed that

> . . . there is hardly anything in the world that some men cannot make a little worse and sell a little cheaper and the people who consider price alone are this man's lawful prey.

This revelation prompted the Air Force to test tires to see which tires cost less per landing over its useful life (10:30). Table 1-1 represents the costs considered for award purposes.

TABLE 1-1

TIRE TEST COMPARISON

Offeror	Unit Cost	Cost per Landing
A	$72.00	3.47
B	79.89	4.71
C	64.30	5.20
D	79.46	6.14

Company C would have won the award under normal procurement methodology due to the lower unit cost. However, company A had the lowest cost per landing and was awarded the contract (21:15). These results showed that buying the cheapest was not the most effective or efficient method. Reliability, which is defined as the probability that material will perform its intended function for a specified period of time under stated conditions (20:576), had to be considered.

Reliability tends to decrease costs of a system over its life, but generally drives up initial costs (12:24-26). Higher initial costs are the result of higher priced materials with lower failure rates and more redundant characteristics being built into the system. The designer determines both reliability and maintainability and can change them depending on consumer demand (12:24).

Maintainability is defined as a characteristic of design and installation expressed as the probability that an item will be restored to a specified condition within a given period of time when the maintenance is performed using prescribed procedures and resources (20:406). A product which is easier to work on requires less maintenance time and thus saves maintenance costs. For example, an automobile engine which must be removed in order to change its spark plugs is not as easily maintained as a standard engine with easy plug access.

The cost of operating and maintaining systems over their useful lives is generally greater than and often several times the initial acquisition cost (9:349). Operating costs account for as much as 75 percent of the total cost of some military weapon systems (9:349).

Support costs make up a large portion of O&M spending and maintenance requirements generate most of the support costs (16:30). Maintenance cost hinges on what must be done to prevent failures and how expensive it is to make the repair. Major maintenance cost considerations involve personnel, support equipment, training and technical manuals (5:27-31). Each system or product has unique characteristics; they may be labor intensive, automated or require a large spares supply. All of these items contribute to operations and support costs.

Summary

This chapter presented the background, problem statement and objectives of the research. The methodology used to determine if there exists significant differences in the life cycle costs of Dodge and Chevrolet pickup trucks will be presented in Chapter II. Chapter III discusses data collection and model development. Conclusions and recommendations will be presented in the fourth chapter.

CHAPTER II

METHODOLOGY

Introduction

Since the Air Force will spend an estimated 2.8 billion dollars over the next five years on the purchase of vehicles, it is imperative that any vehicle acquisition strategy be carefully analyzed using both subjective and quantitative decision aiding approaches (2:39). The methodology portrayed in this chapter provides a quantitative framework to analyze vehicle acquisition policies.

This chapter is presented in three sections. The first section provides the Life Cycle Cost (LCC) model used in the analysis. The next section describes the LCC model data collection plan used to develop an aggregate LCC figure for the vehicles selected for the research. The final section of the chapter establishes the statistical approaches used to analyze the LCC figures.

The Life Cycle Cost Model

Life cycle cost analysis involves the examination of acquisition, operations and maintenance costs incurred over the full life of a vehicle, plus any salvage costs associated with vehicle disposition (3:v). These cost components, which are designated as independent variables,

are aggregated into a total life cycle cost dependent variable as shown in the equation below (1:10):

$$\text{LCC} = \underset{\text{COSTS}}{\text{ACQUISITION}} + \underset{\text{COSTS}}{\text{OPERATIONS \& MAINTENANCE}} + \underset{\text{COSTS}}{\text{SALVAGE}} \qquad (2.1)$$

The acquisition cost component used in this study was the purchase price of vehicles under investigation. Since research and development, engineering design, investment, manufacturing, construction and logistics support costs, as discussed previously in the Blanchard LCC model, are all absorbed by the vehicle manufacturer, they would be passed through to the Air Force as part of the acquisition cost. Therefore, separate accounts are not required for direct analysis of these subcomponents.

Maintenance costs consisted of total labor costs, material cost of repair, and fuel costs to include fuel purchased both on and off base. Operations costs, including drivers' salaries and training costs, were considered to be similar for vehicle types and were therefore excluded from the analysis.

Contract costs are derived from maintenance conducted at commercial sources. These costs occur when the on-base maintenance facility lacks the repair capability. The salvage cost component is added to the model to incorporate any charges for disposal. However, the Air Force generally receives a salvage income through public

auction of vehicles no longer considered useful by Air Force standards (23:A-3). Therefore, salvage values are deducted in the LCC objective function to reflect the incomes received through the auction process. It should be noted that if salvage values for the vehicles under consideration were determined to be equal, the salvage component would be excluded since it would not affect comparative analysis.

Equation 2.2 provides the actual LCC model, derived from the Equation 2.1 general model, which was used in this research:

$$\begin{aligned} LCC = {} & \underset{\text{COST}}{\text{ACQUISITION}} + \underset{\text{COST}}{\text{LABOR}} + \underset{\text{COST}}{\text{MATERIAL}} + \underset{\text{COST}}{\text{FUEL}} \\ & + \underset{\text{COST}}{\text{CONTRACT}} - \underset{\text{VALUE}}{\text{SALVAGE}} \end{aligned} \tag{2.2}$$

<u>Data Collection Plan</u>

Since the Air Force presently buys a number of different models and makes in any one year and distributes them worldwide, finding a single Air Force base or a cluster of bases which had the appropriate numbers and types of vehicles to provide a data base for analysis was not practical. Therefore, it was decided to use a sample of convenience (18:81). A number of bases were visited and Carswell, Tyndall, Beale, Travis, Kelly, Lackland and Randolph were selected for the sample due to the

availability and completeness of vehicle data. The other bases visited had to be rejected from the sample due to incomplete vehicle data files.

In order to determine the LCC dependent variable for each of the forty-three Dodge and twenty-seven Chevrolet trucks in the sample populations, cost data for the independent variables was collected from the following sources:

1. Acquisition Costs--the purchase price of the vehicles was obtained from the Air Force Logistics Command vehicle item manager at the Warner-Robins Air Logistics Center.

2. Maintenance Labor Costs--total labor costs were taken from the Vehicle Integrated Management System (VIMS) Report Number PCN N310031/32.

3. Maintenance Material Costs--material costs were taken from VIMS Report Number PCN N310031/32.

4. Fuel Costs--both on and off base costs were taken from VIMS Report Number PCN N310031/32.

5. Salvage Value--income from vehicle salvage was obtained from the Defense Property Disposal Office (DPDO), Wright-Patterson Air Force Base, Ohio.

6. Contract Maintenance Cost--contract maintenance costs were taken from VIMS Report Number PCN N310031/32.

The Air Force presently requires that the maintenance and fuel cost data previously described be kept on each individual vehicle in the monthly VIMS reports (23:A-3). These reports provide a snapshot of the costs incurred over a vehicle's life and were therefore a convenient source of data for this research. It should be noted that during the course of the year in which data was collected, the PCN N310031 Report was converted to the PCN N310032 Report in the VIMS System. This conversion involved a change to format and was not content related, so that data collected for this research was not affected by the report number change.

Model Development and Analysis

The previous sections of this chapter presented the model used to determine the life cycle costs of Dodge and Chevrolet pickup trucks, and the plan used to collect data for the various components of the model. After the acquisition, material, labor and fuel costs and salvage value data was collected for the representative sample of forty-three Dodge and twenty-seven Chevrolet trucks, average costs and salvage values were computed and added to determine average Dodge and Chevrolet life cycle costs. This section provides the statistical tests used to determine if a significant difference exists between the resulting average life cycle cost figures.

The population from which samples were drawn includes the life cycle costs of all Dodge and Chevrolet pickup trucks in the Air Force inventory, categorized under management code B204. In order to select the specific statistical test to determine if a significant difference exists between the sample mean life cycle costs, the following questions had to be answered (17:219):

1. Do the two populations have a known life cycle cost variance σ^2?

2. Do the two populations have a common life cycle cost variance σ^2?

3. Is the true population mean μ_0 life cycle cost known?

4. What is the size of the two samples used to compute life cycle costs, and are the sample sizes the same?

The overall size and dispersed locations of the total population of Dodge and Chevrolet pickup trucks did not permit the establishment of the population variance or the population mean. Therefore, the statistical test chosen was one where μ_0 and σ^2 are assumed to be unknown. To determine if the two populations have a common variance, we tested the null hypothesis, $\sigma_1^2 = \sigma_2^2$, against the alternate hypothesis, $\sigma_1^2 > \sigma_2^2$. This was accomplished by determining the sample life cycle cost variances s_1^2 and s_2^2, and calculating an F statistic as follows (13:262):

$$F = \frac{\text{the larger } s_1^2}{\text{the smaller } s_2^2}$$

The calculated F was compared to the tabulated values in Table VI of Statistics for Business and Economics by McClave and Benson (13:238). The probability of making an error, referred to as the alpha (α) value, was established as .05 for this test as well as the other statistical analysis used in the research. If the calculated F value was found to be greater than the tabulated F_α, the null hypothesis is rejected, and the appropriate statistical test is one that assumes the two populations do not have a common variance. If the calculated F value was found to be less than the tabulated F_α, we fail to reject the null hypothesis and the appropriate statistical test is one that assumes the two populations have a common variance.

After determining if the two populations have a common variance, the sample sizes of forty-three Dodge and twenty-seven Chevrolet pickup tracks were used to make the final selection of the appropriate statistical test of means of two populations. A summary of Shannon's methodology used to determine which statistic test to use is represented in Figure 2-1 (17:220). The appropriate Z or t statistics were used to test the null hypothesis that there are no differences between the mean life cycle costs of

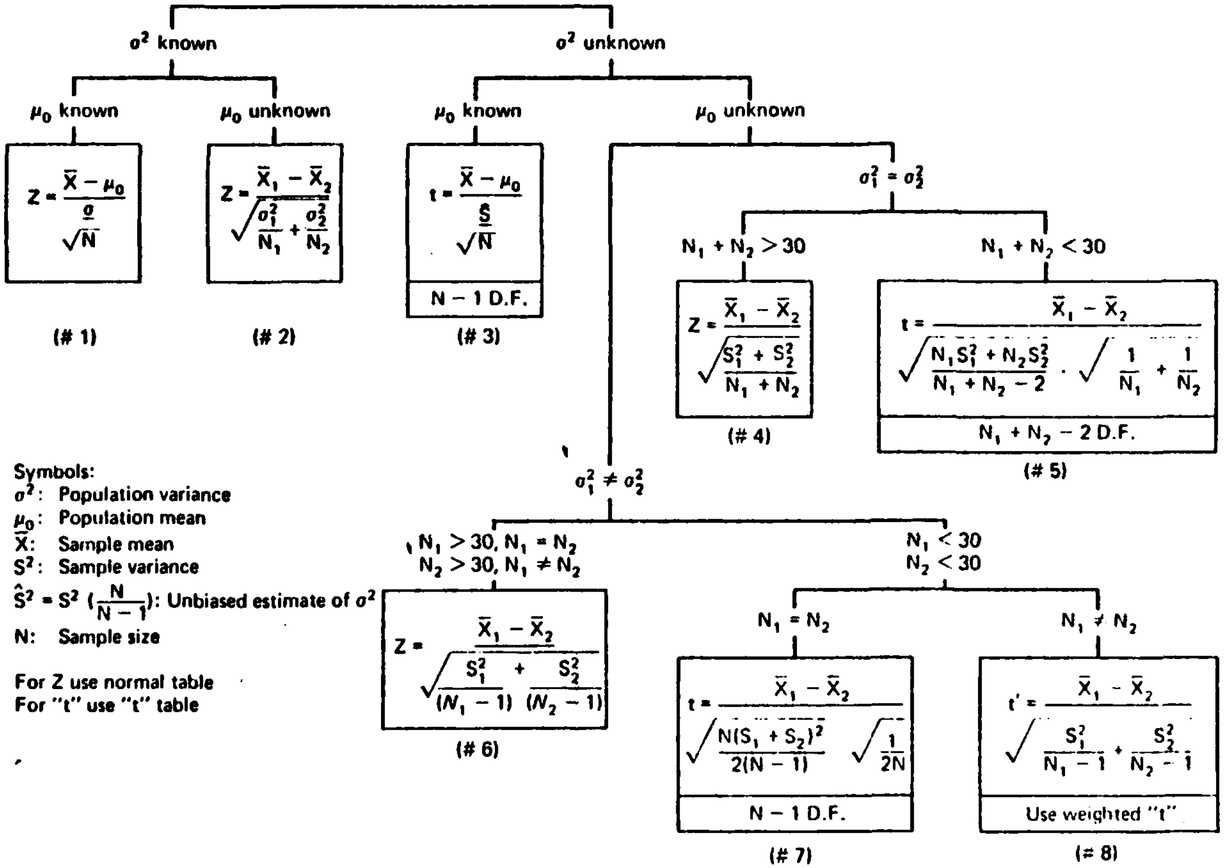

Fig. 2-1. Tests of Means

Dodge and Chevrolet pickup trucks ($\bar{X}_1 = \bar{X}_2$) versus the alternate hypothesis that the means are different ($\bar{X}_1 \neq \bar{X}_2$).

In summary, the statistical test of sample mean life cycle cost data was used to address the first research objective and the associated research question presented in Chapter I: determine if there is a significant difference in the life cycle costs of Chevrolet and Dodge pickup trucks.

After the first research question was answered, Figure 2-2 was used to guide further analysis. Should a substantial difference be revealed, use of the LCC procurement strategy would require reliability and maintainability (RAM) testing in order to establish the LCC data base (8:1). The benefits of cost reduction must be compared to the cost of applying the LCC procurement technique to make the final decision concerning which procurement technique to use.

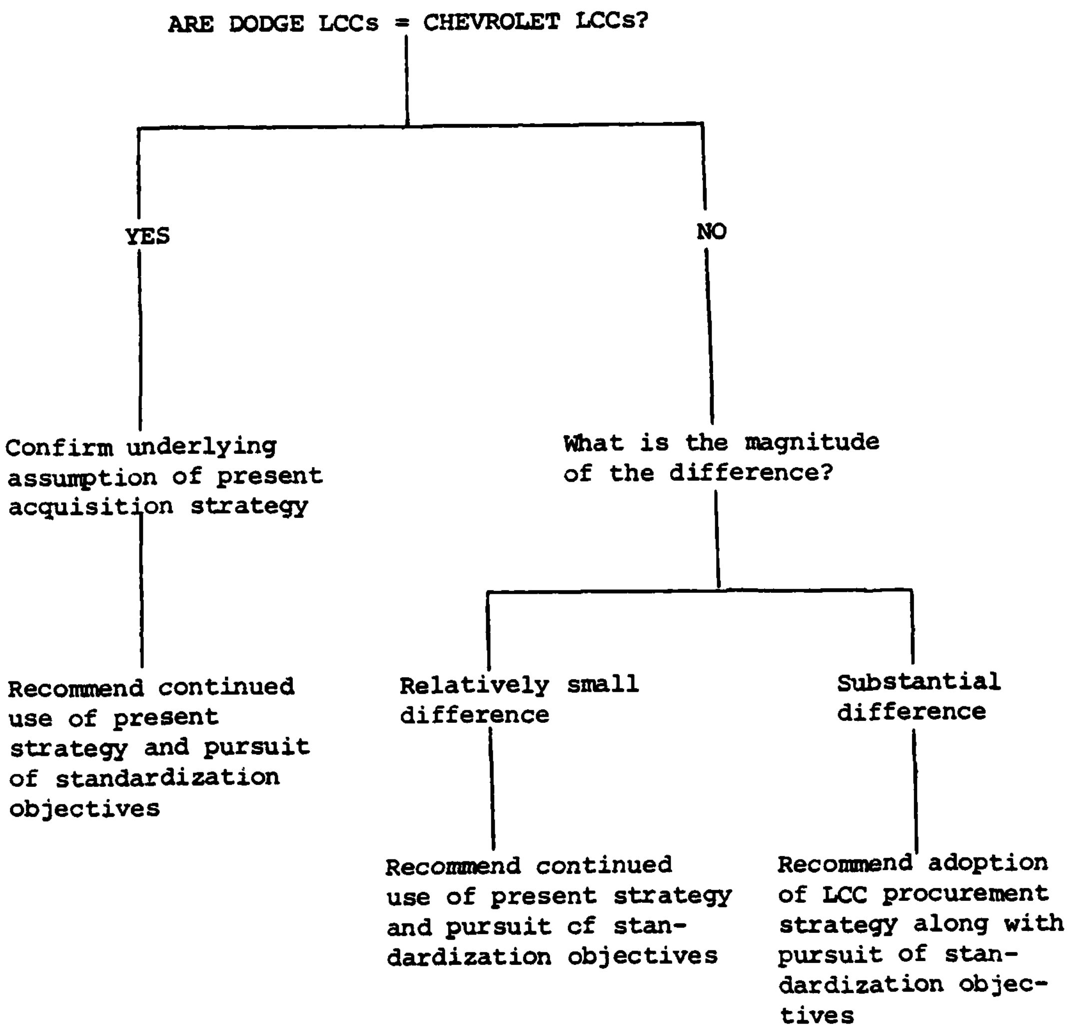

Fig. 2-2. Decision Tree for LCC Analysis

CHAPTER III

DATA COLLECTION AND MODEL DEVELOPMENT

This chapter provides the results of the data collection phase, life cycle cost model development, and the results of the statistical tests. Analysis and conclusions drawn from these results will be addressed in Chapter IV.

This chapter is presented in three sections. The first section provides a tabular presentation of the data collected and used for development of the Life Cycle Cost models for Dodge and Chevrolet pickup trucks. The next section presents a discussion of the life cycle cost models. The final section provides the results of the statistical tests used to determine if there exists a significant difference between Dodge and Chevrolet average life cycle costs.

Results of the Data Collection Phase

Life cycle cost data was collected by individual vehicle registration numbers on a monthly basis, and accumulated for a period of one year. This data is expressed in annual terms in Tables 3-1 and 3-2.

Table 3-1 depicts the data collected for the twenty-seven 1978 sample Chevrolet pickup trucks, and

TABLE 3-1

CHEVROLET VEHICLE DATA

Reg #	Miles	Fuel Cost	Labor Cost	Material Cost	Contract Cost	Total Cost	HOURS		
							VDM	VDP	VOC
78B1556	53,964	5,274.25	7,001.21	653.99	0	12,929.45	420.00	203.00	623.00
78B1557	11,595	1,471.05	1,000.46	411.10	0	2,882.51	114.00	0	114.00
78B1241	8,890	888.36	400.51	362.54	48.75	1,700.16	789.00	5.00	794.00
78B1242	6,381	798.51	133.19	88.20	0	1,019.90	61.00	0	61.00
78B1243	3,819	352.69	165.27	266.24	0	784.20	40.00	0	40.00
78B1244	3,593	377.97	194.26	129.14	0	701.37	138.00	0	138.00
78B1245	13,080	1,410.89	522.20	271.02	357.24	2,561.35	365.00	3.00	368.00
78B1246	11,289	888.96	229.44	75.26	0	1,193.66	50.00	0	50.00
78B1247	7,179	701.31	450.91	154.61	3.95	1,310.78	323.00	0	323.00
78B1248	9,404	1,301.43	395.41	390.15	167.14	2,254.13	250.00	0	250.00
78B1249	10,855	798.51	448.85	126.86	0	1,374.22	120.00	2.00	122.00
78B2967	5,755	574.89	337.74	167.91	0	1,080.54	532.00	0	532.00
78B1231	7,187	607.51	164.43	204.44	0	976.38	39.00	0	39.00
78B1232	4,176	361.69	191.56	62.18	0	615.43	40.00	0	40.00
78B1233	6,740	647.58	430.02	264.05	0	1,341.65	108.00	0	108.00
78B1234	9,856	1,036.36	483.13	394.67	0	1,914.16	499.00	0	499.00
78B1235	5,325	538.61	439.81	394.73	0	1,373.15	158.00	22.00	180.00
78B1259	9,656	748.49	79.68	203.02	0	1,031.19	12.00	0	12.00

TABLE 3-1--Continued

Reg #	Miles	Fuel Cost	Labor Cost	Material Cost	Contract Cost	Total Cost	HOURS VDM	HOURS VDP	HOURS VOC
78B1260	9,604	870.43	278.45	135.07	0	1,283.95	55.00	0	55.00
78B1261	10,308	879.85	215.44	230.09	0	1,325.36	95.00	0	95.00
78B1262	6,745	599.35	115.73	8.58	0	723.66	39.00	0	39.00
78B2966	7,434	812.81	417.85	218.32	0	1,448.96	240.00	0	240.00
78B1354	15,501	1,701.56	351.52	213.97	0	2,267.05	693.00	188.00	881.00
78B1355	16,393	1,375.06	348.65	234.39	0	1,958.10	128.00	0	128.00
78B1356	10,501	1,037.14	128.99	103.43	0	1,269.56	35.00	0	35.00
78B1357	12,877	1,537.96	240.99	139.25	0	1,918.20	109.00	0	109.00
78B1358	7,040	693.64	189.13	160.79	0	1,043.56	203.00	0	203.00
TOTALS	285,147	28,286.86	15,354.83	6,064.00	577.08	50,282.63	5,655.00	423.00	6,078.00
AVE PER VEHICLE	10,561	1,047.66	568.70	224.59	21.37	1,862.32	209.44	15.67	225.11

TABLE 3-2

DODGE VEHICLE DATA

Reg #	Miles	Fuel Cost	Labor Cost	Material Cost	Contract Cost	Total Cost	HOURS VDM	HOURS VDP	HOURS VOC
78B227	7,952	1,538.39	855.85	617.71	0	3,011.95	249.00	247.00	496.00
78B228	18,745	1,643.40	530.23	160.42	0	2,374.05	375.00	0	375.00
78B229	18,990	1,435.57	581.21	638.23	0	2,650.01	68.00	0	68.00
78B230	9,894	1,524.49	548.72	429.98	0	2,503.19	213.00	65.00	278.00
78B231	7,234	966.38	233.26	95.07	0	1,294.71	80.00	0	80.00
78B232	17,572	2,221.33	785.27	181.74	0	3,188.34	124.00	385.00	509.00
78B233	18,502	2,898.48	1,243.88	1,002.71	0	5,145.07	355.00	149.00	504.00
78B234	10,762	1,823.68	767.41	397.39	0	2,988.48	1,018.00	68.00	1,086.00
78B235	14,396	2,205.42	567.34	374.59	0	3,147.35	197.00	66.00	263.00
78B236	15,923	2,829.76	967.22	801.07	0	4,598.05	718.00	515.00	1,233.00
78B237	6,196	896.01	416.41	1,239.04	0	2,551.46	206.00	0	206.00
78B238	16,769	2,536.71	1,087.14	500.97	0	4,124.82	448.00	140.00	588.00
78B239	17,203	1,962.04	350.35	280.01	0	2,592.40	461.00	53.00	514.00
78B240	18,834	2,864.50	1,003.73	963.03	0	4,831.26	508.00	20.00	528.00
78B241	15,284	2,488.38	1,296.15	593.90	0	4,378.43	607.00	167.00	774.00
78B242	14,497	1,158.99	301.15	112.38	0	1,572.52	81.00	0	81.00
78B243	7,648	1,083.67	92.92	235.85	0	1,412.48	9.00	0	9.00
78B244	8,900	929.93	274.96	358.42	0	1,563.31	209.00	0	209.00

TABLE 3-2--Continued

Reg #	Miles	Fuel Cost	Labor Cost	Material Cost	Contract Cost	Total Cost	HOURS VDM	HOURS VDP	HOURS VOC
78B245	4,447	483.60	192.52	0	0	676.12	5.00	0	5.00
78B246	13,034	1,660.97	602.69	443.33	0	2,706.99	256.00	0	256.00
78B247	9,685	1,283.12	384.78	808.20	0	2,476.10	107.00	0	107.00
78B248	10,788	1,031.51	216.13	0	0	1,247.64	54.00	0	54.00
78B249	14,620	1,612.86	312.75	45.49	0	1,971.10	65.00	0	65.00
78B250	16,361	1,875.00	333.81	593.93	0	2,802.74	6,413.00 TOTAL	1,875.00 TOTAL	8,288.00 TOTAL
78B251	6,992	1,198.41	525.61	339.67	0	2,063.69			
78B252	11,118	2,681.34	1,018.26	571.09	0	4,270.69	278.82 AVERAGE	81.52 AVERAGE	360.34 AVERAGE
78B253	22,033	3,924.81	695.94	1,113.68	0	5,734.43			
78B254	9,516	1,087.47	493.82	142.26	0	1,723.55			
78B255	22,942	4,682.69	1,267.76	928.53	0	6,878.98			
78B256	16,696	2,704.10	1,423.44	734.99	0	4,862.53			
78B257	12,207	1,253.19	379.50	298.84	0	1,931.53			
78B258	20,430	3,325.22	983.44	1,368.91	0	5,677.57			
78B259	6,086	762.65	244.88	692.89	0	1,700.42			
78B260	18,905	2,411.23	862.58	753.68	0	3,273.81			
78B261	15,924	2,058.97	648.60	374.99	0	2,707.57			
78B262	19,670	3,380.03	1,013.71	923.17	0	5,316.91			
78B263	8,337	1,045.88	995.43	883.95	0	2,925.26			

TABLE 3-2--Continued

Reg #	Miles	Fuel Cost	Labor Cost	Material Cost	Contract Cost	Total Cost
78B264	24,965	2,900.39	857.47	353.88	0	4,111.74
78B265	12,712	1,690.31	331.42	181.76	0	2,203.49
78B266	9,388	1,405.02	331.88	54.45	0	1,791.35
78B267	5,438	993.31	347.51	300.15	0	1,640.97
78B258	9,146	1,203.94	596.56	364.86	0	1,860.07
78B269	7,984	944.52	482.25	430.55	0	1,857.32
TOTALS	574,725	80,607.67	27,445.94	24,385.76	0	132,439.37
AVE PER VEHICLE	13,365,698	1,874.60	638.28	567.11	0	3,079.99

Table 3-2 provides the data collected for the forty-three 1978 sample Dodge pickup trucks. The tables provide the fuel, labor, material and contract cost elements by individual vehicle registration number as well as total and average cost summaries for these elements.

Other information reported in Tables 3-1 and 3-2 includes miles driven and statistics on the hours each vehicle was out of commission (VOC). The VOC statistic is further divided into the hours the vehicles were out of commission because of maintenance (VDM) or because parts were not available (VDP). This additional information will be addressed in Chapter IV.

Life Cycle Cost Model Development

The next step in the analysis required development of the life cycle cost models for the Dodge and Chevrolet pickup trucks. The models were expressed in the form of Equation 2.2, discussed in Chapter II, and repeated below as Equation 3.1.

$$\begin{aligned} LCC = {} & \underset{\text{COST}}{\text{ACQUISITION}} + \underset{\text{COST}}{\text{LABOR}} + \underset{\text{COST}}{\text{MATERIAL}} + \underset{\text{COST}}{\text{FUEL}} \\ & + \underset{\text{COST}}{\text{CONTRACT}} - \underset{\text{VALUE}}{\text{SALVAGE}} \end{aligned} \tag{3.1}$$

The labor, material, fuel and contract cost components were the average cost figures taken from Tables 3-1 and 3-2.

Acquisition and salvage costs for both vehicle types were found to be equal. The item manager at Warner-Robins stated that both vehicles were purchased at a cost of $4,255 (15). This does not include transportation costs to each individual destination. Transportation costs cannot be determined precisely due to variances in destination and will not be addressed. Salvage value of $350 applied for both Dodge and Chevrolet pickup trucks (7). Since the acquisition and salvage costs were equal, a modification of Equation 3.1 is necessary. Equation 3.2 now represents the appropriate model in which the average yearly LCC was derived.

$$LCC = \underset{\text{COST}}{\text{LABOR}} + \underset{\text{COST}}{\text{MATERIAL}} + \underset{\text{COST}}{\text{FUEL}} + \underset{\text{COST}}{\text{CONTRACT}} \tag{3.2}$$

The resultant life cycle cost (LCC_D) model for the Dodge pickup trucks is now shown in Equation 3.3.

$$LCC_D = 638.28 + 567.11 + 1874.60 + 0 = 3079.99 \tag{3.3}$$

The resultant life cycle cost (LCC_C) model for the Chevrolet pickup trucks is shown in Equation 3.4.

$$LCC_C = 568.70 + 224.59 + 1047.66 + 21.57 = 1862.52 \tag{3.4}$$

Statistical Analysis

The next step in the research involved the determination of whether the life cycle costs for the Dodge

pickup trucks were statistically equal to the life cycle costs of the Chevrolet pickup trucks.

In order to determine the appropriate statistical test of the two sample mean life cycle costs, it was first necessary to determine whether the variances of the two populations were equal, using the following F test:

$$F = \frac{s_1^2 \text{ Largest}}{s_2^2 \text{ Smallest}}$$

where,

$$s^2 = \frac{(\text{sum of squares of sample}) - (\text{sum of sample means})^2}{N-1}$$

The sample variances for the Chevrolet and Dodge pickup trucks were computed as follows:

$$s_1^2 \text{ (Chevrolet)} = \frac{(2.2947 \times 10^8) - (93642329)}{26} = 5,224,910$$

$$s_2^2 \text{(Dodge)} = \frac{(4.7079 \times 10^8) - (4.0791 \times 10^8)}{42} = 1,497,135$$

The calculated F value was then computed as:

$$F = \frac{5,224,910}{1,497,135} = 3.4899$$

Since the calculated F value was greater than the tabulated F value of 1.848, using a confidence level of .05 and 26

and 42 degrees of freedom, it was concluded that the variances of the Chevrolet and Dodge pickup trucks were not equal.

The above results, together with the sample size information, led to the use of Equation 6 in Figure 2-1 to test whether there is a difference between Dodge and Chevrolet sample life cycle cost averages (17:220). This equation is repeated below:

$$Z = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{\frac{s_1^2}{(N_1-1)} + \frac{s_2^2}{(N_2-1)}}}$$

and is used to test the null hypothesis, $LCC_D = LCC_C (\overline{X}_1 = \overline{X}_2)$, against the alternative hypothesis, $LCC_D \neq LCC_C (\overline{X}_1 \neq \overline{X}_2)$.

The Z test statistic was then calculated as follows:

$$Z = \frac{3079.99 - 1862.32}{\sqrt{\frac{5224910}{26} + \frac{1497135}{42}}} = 2.5033$$

The critical value used for comparison of the calculated Z statistic was determined from $\alpha/2$ value of .025 which equals 1.96. Since the calculated Z value of 2.5033 exceeds 1.96, the null hypothesis is rejected in favor of the alternate hypothesis. Thus it was determined that

there exists a significant difference between the average life cycle costs of the Chevrolet and Dodge pickup trucks, not based upon randomness or chance alone. This result will be analyzed and other conclusions will be presented in Chapter IV.

CHAPTER IV

CONCLUSIONS AND RECOMMENDATIONS

With the ever-increasing emphasis on Department of Defense spending, it is important to investigate new and innovative methods of reducing outlays. With vast sums of money spent each year on the purchase of commercial vehicles, this field may present the opportunity for application of cost reduction techniques. Life Cycle Cost procurement is one technique that may offer the opportunity for such cost reduction.

The results of this research indicate that there is a statistically significant difference in the average life cycle costs of Dodge and Chevrolet pickup trucks, a difference not based upon randomness or chance alone. The following LCC model summarizes the average yearly operating and maintenance cost along with the acquisition and salvage components.

$$\text{LCC} = \text{ACQUISITION} + \text{LABOR} + \text{MATERIAL} + \text{FUEL} + \text{CONTRACT} - \text{SALVAGE}$$

$$\text{DODGE} = 4255 + 638.28 + 567.11 + 1874.60 + 0 - 350 = 6984.99$$

$$\text{CHEVROLET} = 4255 + 568.70 + 224.59 + 1047.66 + 21.37 - 350 = 5767.32$$

Acquisition and salvage costs are equal and did not contribute to the difference in total life cycle costs. The operations and maintenance components were the factors

that created the cost variance between Dodge and Chevrolet pickup trucks. Based on the sample data, it was concluded that the Air Force spends an average of $3080 to operate and maintain a Dodge pickup truck for a year and only $1862 to operate and maintain a Chevrolet pickup truck resulting in a difference of $1218. Multiplying this difference by the life expectancy of seven years for a pickup truck, results in a difference of $8524 per vehicle. If the Air Force buys 500 pickup trucks per year, the average difference in operating and maintaining the two makes results in a total difference of 4,261,845 dollars. A figure of this magnitude serves to point out the importance of choosing the proper procurement strategy. Table 4-1 illustrates the above computations.

TABLE 4-1

LCC COMPUTATION EXAMPLE

Dodge Average O&M Costs	3079.99
Chevrolet Average O&M Costs	1862.22
Difference Between the Two Makes	1217.67
Air Force Vehicle Life Expectancy	X7
	8523.99
Number of Vehicles Bought	X500
Total Difference	4,261,865

Further analysis and conclusions will be presented in the context of the decision tree presented in Chapter II and repeated in Figure 4-1.

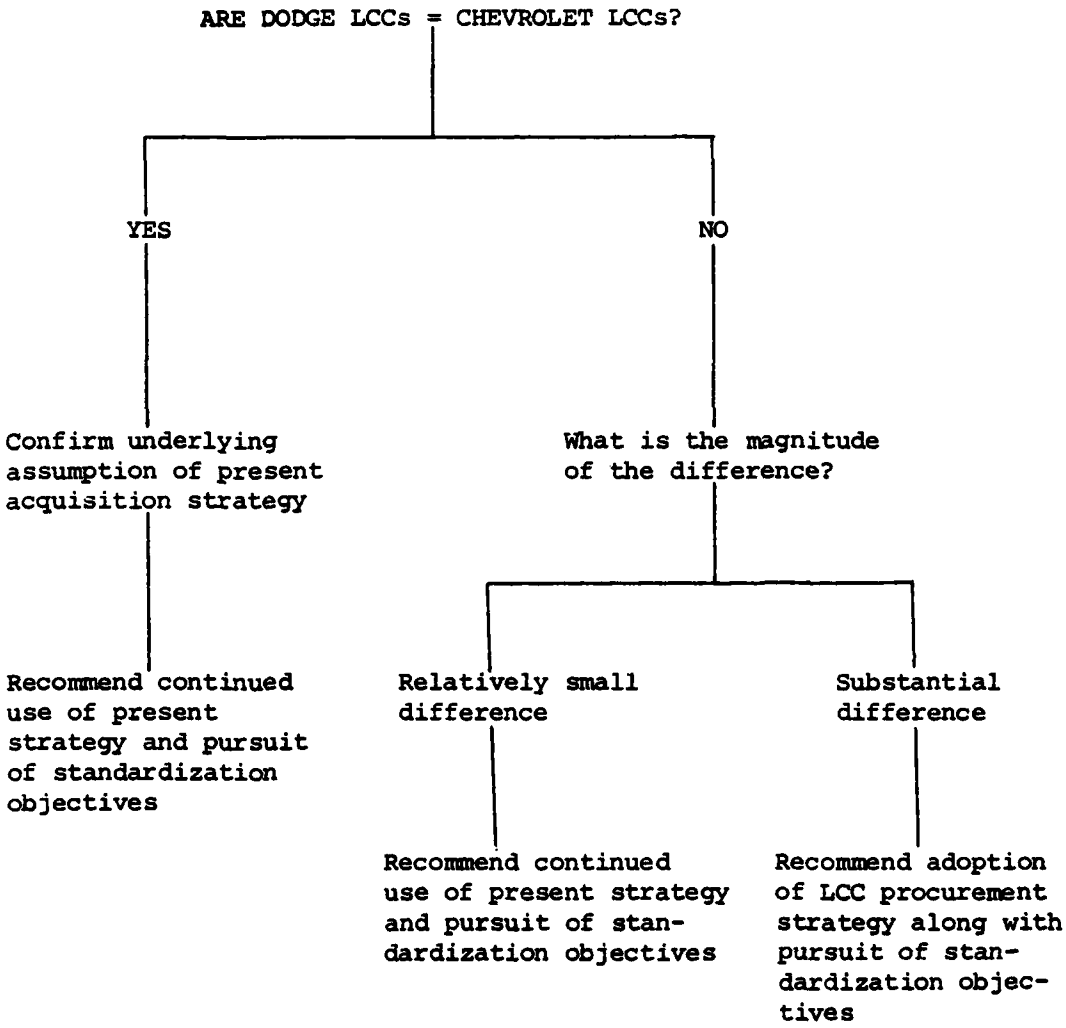

Fig. 4-1. Decision Tree for LCC Analysis

Our research indicates that the average Life Cycle Costs of Dodge and Chevrolet are different. The research further shows that difference is substantial, especially after multiplying the per vehicle difference by the number of vehicles procured in a year's time and by the number of years in the vehicles' life cycle. With the advent of block, family, and multiyear buy programs, the magnitude of the difference in average life cycle cost increases. This suggests that a life cycle procurement strategy should be considered for adoption along with a pursuit of standardization objectives. Of course, using LCC procurement strategy requires reliability and maintainability (RAM) testing in order to establish the LCC data base. Because RAM testing is expensive and time-consuming, LCC procurement would not be suited for small scale vehicle buys, but should be considered for the multiyear and other large scale buy programs.

The following hypothetical example illustrates the potential impact of multiyear procurement on life cycle costs. If the Air Force was to purchase 500 Dodge as opposed to 500 Chevrolet pickup trucks the excess cost would be 4,261,845 over a seven-year life span. If the Air Force was to make a three-year multiyear buy of 500 Dodge pickup trucks per year, the excess cost would triple to 12,785,535. This further amplification of cost

differences vividly portrays the importance of choosing the most economical vehicle to own and operate over its entire life.

During the process of our study further evidence was found to substantiate our claim that there was a difference in average life cycle cost of Dodge and Chevrolet pickup trucks. Though the following figures were not statistically tested, they are presented as additional evidence. Average yearly vehicle out-of-commission (VOC) time for a Dodge pickup was 360.34 hours compared to 225.11 hours for a Chevrolet pickup. Both components of VOC, vehicles awaiting maintenance (VDM) and vehicles awaiting parts (VDP) were higher for a Dodge pickup truck than for a Chevrolet pickup truck. These VOC, VDM, and VDP factors serve as the major cost drivers which resulted in the average LCC differences between the two vehicle makes, as well as the differences in the cost per mile statistic. The cost per mile for Dodge pickup trucks (23 cents per mile) was considerably higher than for Chevrolet pickup trucks (17 cents per mile).

In conclusion, this study represented a research effort designed to analyze the Air Force's procurement strategies and the potential application of life cycle cost techniques. Still, in light of the assumptions made and the limited scope of the research, further study in this

area is suggested. Specifically, the two authors make the following recommendations:

1. That the methodology used in this study be applied to other types of Air Force vehicles. For example, sedans, one-ton trucks, one and one-half-ton trucks, and telephone maintenance trucks are likely candidates for this type of research. With the proper authoritative guidance and direction, the present VIMS computer software package could be used to compile and analyze existing vehicle cost information.

2. That the feasibility of applying reliability and maintainability (RAM) testing to the procurement of general purpose vehicles be investigated. Cost/benefit analysis could be used to determine whether the application of RAM testing is feasible.

3. That the impact of make and model proliferation on life cycle vehicle cost be studied. Make and model proliferation has only been studied qualitatively by the Air Force. The Air Force believes that make and model proliferation increases total vehicle fleet costs by increasing the cost for the stocking of spare parts, the administration of technical data, and the training of mechanics. Based on their past experience, the researchers support this hypothesis. Ways to quantify these costs should be explored.

The goal of the Air Force vehicle fleet management program and, in particular, procurement strategies, is to provide reliable vehicles to support the Air Force mission at the lowest total life cycle cost. This research team feels very confident that the implementation of these recommendations would insure the attainment of a more standardized vehicle fleet. This would therefore provide a more reliable fleet to meet the Air Force mission while at the same time save money.

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